Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/EP04/053440

International filing date: 14 December 2004 (14.12.2004)

Document type: Certified copy of priority document

Document details: Country/Office: EP
Number: 03293195.8
Filing date: 17 December 2003 (17.12.2003)

Date of receipt at the International Bureau: 16 February 2005 (16.02.2005)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

PCT/EP2004/053440

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14. 12. 2004

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Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

03293195.8

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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EPA/EPO/OEB Form 1014.1 - 02.2000 7001014

Anmeldung Nr:
Application no.: 03293195.8
Demande no:

Anmeldetag:
Date of filing: 17.12.03
Date de dépôt:

Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Method and device for compensating load effect

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
Staat/Tag/Aktenzeichen/State/Date/File no./Pays/Date/Numéro de dépôt:

Internationale Patentklassifikation/International Patent Classification/
Classification internationale des brevets:

G09G/

Am Anmeldetag benannte Vertragstaaten/Contracting states designated at date of filing/Etats contractants désignées lors du dépôt:

AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IT LU MC NL
PT RO SE SI SK TR LI

METHOD AND DEVICE FOR COMPENSATING LOAD EFFECT

The present invention relates to a method for processing data of a picture to be displayed on display means with persistent luminous elements during a frame comprising a plurality of subfields of at least two different weights.

Background

High contrast is an essential factor for evaluating the picture quality of every display technologies. From this perspective, a high peak-white luminance is always required to achieve a good contrast ratio and, as a result, a good picture performance even with ambient light conditions. Otherwise, the success of a new display technology requires also a well-balanced power consumption. For every kind of active display, more peak luminance corresponds also to a higher power that flows in the electronic of the display. Therefore, if no specific management is done, the enhancement of the peak luminance for a given electronic efficacy will lead to an increase of the power consumption. So, it is common to use a power management concept to stabilize the power consumption of the display. The main idea behind every kind of power management concept associated with peak white enhancement is based on the variation of the peak luminance depending on the picture content in order to stabilize the power consumption to a specified value as illustrated on figure 1. In this figure, the peak luminance decreases as the picture load increases. The power consumption is kept constant.

The concept described on figure 1 enables to avoid any overloading of the power supply as well as a maximum contrast for a given picture. Such a concept suits very well to the human visual system, which is dazzled in case of full white picture (picture load=100%) whereas it is really sensitive to dynamic in case of dark picture (e.g. dark night with a moon). Therefore, in order to increase the impression of high contrast on dark picture, the peak luminance is set to very high values whereas it is reduced in case of energetic pictures (full white).

In the case of analog displays like Cathode Ray Tubes (CRTs), the power management is based on a so called ABM function (Average Beam-current Limiter), which is implemented by analog means, and which decreases video gain as a function of average luminance, usually measured over a RC stage. In the case of a plasma display, the luminance as well as the power consumption is directly linked to the number of sustain pulses (light pulses) per frame. As shown on Figure 2, the number of sustain pulses for peak white decreases as the picture load, which corresponds to the Average Power Level (APL) of the picture, increases for keeping constant the power consumption.

The computation of the Average Power Level (APL) of a picture P is for example made through the following function :

$$APL(P) = \frac{1}{C \times L} \cdot \sum_{x,y} I(x,y)$$

where I(x,y) represents the luminance of a pixel with coordinates (x,y) in the picture P, C is the number of columns and L is the number of lines of the picture P.

Then, for every possible APL values, a maximal number of sustain pulses is fixed for the peak white pixels for keeping constant the power consumption of the PDP. Since, only an integer number of sustain pulses can be used, there is only a limited number of available APL values. In theory, the number of sustain pulses that can be displayed for the peak white pixels can be very high. Indeed, if the picture load tends to zero, the power consumption tends also to zero, and the maximal number of sustain pulses for a constant power consumption tends to infinite. However, the maximal number of sustain pulses defining the maximal peak white (peak white for a picture load of 0%) is limited by the available time in a frame for the sustaining and by the minimum duration of a sustain pulse. Figure 3 illustrates the duration and the content of a frame comprising 12 subfields having different weights, each subfield comprising an addressing period for activating the cells of the panel and a sustaining period for illuminating the activated cells of the panel. The duration of the addressing period is identical

for each subfield and the duration of the sustaining period is proportional to the weight of the subfield. When the picture load is high, the number of cells consuming energy at a given time is high; so, the duration of the sustaining period should be reduced for keeping constant the average power consumption. That is the reason why the sustaining duration for a frame is higher for a low picture load than for a high picture load.

In addition, in order to achieve a high maximal peak white, the number of subfield is kept to a minimum ensuring an acceptable grayscale portrayal (with few false contour effects), the addressing speed is increased to a maximum keeping an acceptable panel behavior (response fidelity) and the sustain pulse duration is kept to a minimum but having an acceptable efficacy.

But, at this stage, PDP makers are faced with an other problem called load effect explained below. As previously mentioned, a high peak white requires to be able to shorten the duration of a sustain pulse. However, this increase of the sustain frequency has a strong drawback: it increases load effect, especially, when the xenon percentage in the gas of the PDP cells is high. This effect is illustrated by figure 4. Losses due to line capacity effect occur and have a strong influence on the panel luminance for a high sustain frequency when the xenon percentage in the cells is high (what is required usually for a high efficacy). The white horizontal lines of the cross are less luminous in a high sustain frequency mode (right part of Figure 4) than in a low sustain frequency mode (left part). This example shows a line load effect. However, the effect is not only linked to line load. Indeed, if a subfield is globally more used than another one on the whole screen, it will have less luminance per sustain pulse due to this load effect (the losses occur in the screen and in the electronic circuitry).

Therefore, on the one hand, a high number of sustain pulse and a high sustain frequency are required for peak white modes and, on the other hand, the panel will lose its homogeneity in case of peak white modes. This can have dramatic effects on artificial pictures like slides as well as on natural scene as shown in Figure 5. The load effect has an impact on the

grayscale portrayal under the form of a kind of solarization effect which looks like a lack of gray levels. In that case, the right picture seems to be coded with fewer bits than the left one. This is due to the fact that suddenly, some subfields are less luminous than they should be. In that case, if we consider two video levels that should have similar luminance, and if one of them is using such a subfield, its global luminance will be too low compared to the other video level introducing such disturbing effect.

In order to better understand the load effect issue, the load distribution for all subfields of two test pictures given at figure 6 are analyzed below. The first test picture represents a woman with flowers and the second one is a European man.

The load per subfield for the first test picture is given by the following table :

Sub-field	Weigth	Load
1	1	76.05%
2	2	83.56%
3	3	68.54%
4	5	60.81%
5	8	54.92%
6	12	42.53%
7	18	31.90%
8	27	21.60%
9	41	12.96%
10	58	0.27%
11	80	0.07%

The load of a subfield is the amount (or number) of activated cells of the panel during said subfield. In this table, the subfield load is expressed as a percentage of the total amount of cells of the panel. For example, the percentage of 76,05% for the first subfield means that the first subfield is activated for 76,05% of the pixels of the first test picture.

The load per subfield for the second test picture is given by the following table :

Sub-field	Weigth	Load
1	1	63.24%
2	2	74.69%
3	3	73.94%
4	5	79.73%
5	8	88.45%
6	12	77.34%
7	18	32.67%
8	27	81.26%
9	41	12.12%
10	58	3.94%
11	80	0.43%

As shown by histograms in the right part of Figure 6, the subfield loads are depending on the picture to be displayed.

In order to illustrate the problem, let us take the example of the second picture (European man) and its subfield loads. It can be seen that the first 6 subfields are quite loaded whereas the seventh one is less loaded. Now, let us take two video levels that are present in the man's face and that should have almost similar luminance:

- The first code [11111100000] corresponds to the video value 31 and utilizes only the six first subfields whose respective subfield loads are comprised between 63.24% and 88.45%. But, it can be determined, for example by measurement of the light emitted by luminous elements of the PDP during these subfields (this measurement stage will be more detailed in reference of the invention), that there is a global luminance attenuation of around 70% for all these subfields. Finally, the visual impression is around 31x0.7=21.7 instead of 31.
- The second code [11101010000] corresponds to the video value 32 and utilizes the seventh subfield (load of 32.67%) plus 4 from the six firsts (load from 63.24% to 79.73%). The first subfields (among the six first ones) have a global luminance attenuation of around 70% as previously mentioned whereas the seventh subfield has only an attenuation of 86.74%. In that case the visual impression obtained is (1+2+3+8)*0.7+18x0.86=25.28 instead of 32.

Then, instead of having a video difference of 3% (32-31), we have now a difference of 16% (25.28-21.7). This will introduce an artificial quantization effect, called mainly solarization, which looks like a lack of gray levels. In

fact, it is a non linearity in the gray levels. As a general matter, this phenomenon is called load effect.

Invention

The invention relates to a method and a device for compensating such a load effect in a display panel with persistent luminous elements.

The invention concerns a method for processing data of a picture to be displayed on display means with persistent luminous elements during a frame comprising a plurality of subfields of at least two different weights, a number of sustain pulses being associated to each subfield. It comprises the following steps :

- encoding the picture data into subfield data,
- calculating the load of each subfield on the basis of said subfield data, and
- adjusting the number of sustain pulses of the subfields on the basis of their load in order to have a same relation of proportionality between the luminance produced by the persistent luminous elements for the subfields and their weights.

For adjusting the number of sustain pulses of a subfield, the method comprises the following steps :

- providing a first number of sustain pulses for said subfield,
- defining a correction value to be subtracted to said first number of sustain pulses on the basis of the load and the number of sustain pulses of said subfield,;
- subtracting said correction value from said first number of sustain pulses in order to have a second number of sustain pulses for said subfield.

In a preferred embodiment, the correction values of the subfields are defined by a look up table with the load and the number of sustain pulses of the subfields as input signals. The correction values stored in the look up table can be achieved in at least two different ways.

In a first embodiment, the corrections values are computed by :

- measuring the luminance produced by a plurality of luminous elements of the display means for all first numbers of sustain pulses comprised between 1 and the first number of sustain pulses M of the highest weight subfield and for a plurality of non-zero loads,
- determining, for each one of said first numbers of sustain pulses and each one of said loads, the luminance attenuation compared with a reference luminance measured for the same number of sustain pulses and the highest one of said loads, and
- computing, for each one of said first numbers of sustain pulses and each one of said loads, the correction value by multiplying the determined luminance attenuation with said first number of sustain pulses.

In a second embodiment, since the attenuation does not much vary with the number of sustain pulses, it is also possible to compute the correction values for a specific number of sustain pulses. In this case, the correction values included in the look up table are achieved by the following steps :

- measuring the luminance produced by a plurality of luminous elements of the display means for a specific first number of sustain pulses and for a plurality of non-zero loads,
- determining, for each one of said loads, the luminance attenuation compared with a reference luminance measured for the highest one of said loads, and
- computing, for each one of said loads and for said specific first number of sustain pulses, the correction value by multiplying the determined luminance attenuation with said specific first number of sustain pulses.

In order to avoid measurement errors, the specific first number of sustain pulses is preferably greater than 20.

In an improved embodiment, the inventive method comprises further a step for rescaling the second numbers of sustain pulses of the plurality of

subfields in order to redistribute in each subfield an amount of the subtracted sustain pulses proportionally to its second number of sustain pulses.

In another improved embodiment, before the step of adjusting the number of sustain pulses of each subfield on .the basis of its load, said number of sustain pulses is rescaled in order that the average power level needed by the display means for displaying the picture be approximately equal to a fixed target value.

The invention concerns also a device for processing data of a picture to be displayed on display means with persistent luminous elements during a frame comprising a plurality of subfields of at least two different weights, a number of sustain pulses being associated to each subfield, characterized in that it comprises :

- means for encoding the picture data into subfield data,
- means for calculating the load of each subfield on the basis of said subfield data, and
- means for adjusting the number of sustain pulses of the subfield on the basis of their loads in order to have a same relation of proportionality between the luminance produced by the persistent luminous elements for the subfields and their weights.

The invention concerns also a plasma display panel comprising a plurality of persistent luminous elements organized in rows and columns and said device for compensating load effect.

<u>drawings</u>

Exemplary embodiments of the invention are illustrated in the drawings and are explained in more detail in the following description, the drawings showing in :

Fig.1 a diagram representing the peak luminance and the power consumption according to the picture load in a classical plasma display panel;

Fig.2 a diagram representing the number of sustain pulses for peak white according to the picture load in a classical plasma display panel;

Fig.3 the time duration of a frame according to picture load in a classical plasma display panel;

Fig.4 the load effect in a classical plasma display panel when the sustain frequency is high;

Fig.5 the solarization effect on a natural scene due to load effect;

Fig.6 two test pictures and two associated histograms showing the load per subfield for the two test pictures;

Fig.7 a diagram showing the luminance efficacy according to load;

Fig.8 a block diagram of a circuit implementation of a plasma display device according to the invention; and

Fig.9 a LUT comprising correction values to be subtracted to the number of sustain pulses of each subfield in order to compensate load effect.

exemplary embodiments

According to the invention, the number of sustain pulses of each subfield is adjusted to compensate the load effect. A correction value is calculated for each subfield. This value, depending on the load and the number of sustain pulses of the subfield, is subtracted to the number of sustain pulses of the subfield.

Preferably, the subtracted sustain pulses are redistributed to the subfields proportionally to their new amount of sustain pulses in order to avoid a loss of luminance (a reduced peak luminance).

Preferably, the adjusting step is implemented after the computation of the picture load, for example by calculating the Average Power Level (APL), and after the rescaling of the number of sustain pulses of each subfield in order to keep constant the power consumption of the display panel.

In the presented embodiments, each video data are encoded into 11 bit data (1 bit for each subfield) and the 11 subfields have the following weights :

$$1 - 2 - 3 - 5 - 8 - 12 - 18 - 27 - 41 - 58 - 80\ (\Sigma=255)$$

In a facultative preliminary step, the numbers of sustain pulses of the subfields are rescaled, for example by APL as shown in FIG.3, in order to keep constant the power consumption. At the end of this step, the maximal peak white can vary from 200 sustain pulses up to 1080 sustain pulses.

The load effect compensating method comprises three steps :
- a subfield load computation step;
- an step of adjusting the number of sustain pulses per subfield according to subfield load; and
- preferably, a step of redistribution of the subtracted sustain pulses.

Subfield load computation

This step consists in counting the luminous elements that are to be illuminated during each subfield for the picture to be displayed.

This step can be easily implemented by using, for each subfield, a counter counting the subfield data corresponding to luminous elements "ON".

Adjusting step of sustain pulses

This step leads in the definition of a number of sustain pulses for each subfield minimizing the load effect.

For a peak white value with 1080 sustain pulses, the number of sustain pulses of the highest weight subfield is 80/255*1080=339. So, in order to determine the attenuation of all subfields due to load effect, it is necessary to measure the panel luminance behavior from a minimum of 1 sustain pulse up to a maximum of 340 sustain pulses. Obviously, not all

values have to be measured but rather a subset of values. The other values are calculated by interpolation since load effect is more or less a proportional effect.

The measurement is for example carried out on a square area of the screen. The picture load is made evolving from, for example, 8.5% up to 100%. The gray levels in this area are coded with only one subfield having successively all sustain pulses numbers of the subset. An example of measurement results is presented on the table below for only some measuring points (from 1 sustain pulse to 130 sustain pulses with load varying from 8.5% to 100%). The luminance behavior results are expressed in candela per square meter (cd/m²). The load is given vertically in the left column of the table and the number of sustain pulses is given horizontally in the top row of the table. This table comprises a reduced amount of values to simplify the exposition of the invention.

	Sustain pulses number																
Load (%)	1	2	4	8	10	20	30	40	50	60	70	80	90	100	110	120	130
8.50%	1.20	2.37	4.66	9.19	11.31	22.29	32.92	43.20	53.15	62.75	72.01	80.93	89.50	97.73	105.62	113.17	120.37
12.00%	1.19	2.33	4.58	9.02	11.10	21.81	32.25	42.34	52.06	61.64	70.49	79.36	87.65	95.68	103.72	110.81	118.37
14.50%	1.18	2.31	4.52	8.88	10.92	21.49	31.71	41.65	51.24	60.49	69.49	77.90	86.18	94.40	101.86	108.25	116.03
17.00%	1.18	2.28	4.47	8.76	10.79	21.16	31.28	41.11	50.53	59.48	68.38	76.89	85.00	92.78	100.27	107.46	114.11
19.50%	1.17	2.26	4.41	8.64	10.62	20.84	30.78	40.49	49.76	58.68	67.30	75.63	83.65	91.33	98.97	105.84	112.59
21.00%	1.16	2.25	4.38	8.56	10.52	20.66	30.55	40.10	49.35	58.09	66.78	75.01	82.89	90.55	97.90	104.98	111.40
23.00%	1.15	2.23	4.34	8.49	10.42	20.41	30.16	39.74	48.77	57.48	65.98	74.10	82.01	89.47	96.94	103.71	110.28
24.50%	1.14	2.22	4.31	8.41	10.33	20.26	29.89	39.34	48.40	56.92	65.47	73.55	81.25	88.79	95.97	102.76	109.19
26.00%	1.13	2.20	4.28	8.33	10.24	20.05	29.65	38.99	47.95	56.49	64.80	72.77	80.30	87.89	95.08	101.94	107.49
27.00%	1.12	2.19	4.25	8.29	10.18	19.93	29.45	38.79	47.69	56.11	64.43	72.32	80.13	87.46	94.59	101.28	107.59
29.00%	1.11	2.15	4.20	8.21	10.08	19.75	29.12	38.36	47.12	55.47	63.79	71.63	79.24	86.46	93.51	100.31	106.34
30.00%	1.10	2.13	4.17	8.15	10.01	19.59	28.96	38.15	46.79	55.15	63.32	71.07	78.66	85.89	92.98	99.53	105.77
31.00%	1.09	2.11	4.13	8.10	9.95	19.47	28.77	37.90	46.51	54.80	62.91	70.69	78.18	85.39	92.37	98.93	105.07
32.50%	1.09	2.09	4.09	8.02	9.87	19.32	28.56	37.58	46.00	54.39	62.40	70.06	77.64	84.63	91.56	98.18	104.38
33.50%	1.09	2.08	4.05	7.92	9.79	19.19	28.35	37.29	45.68	53.98	61.91	69.61	76.70	84.17	91.05	97.48	103.52
34.50%	1.08	2.07	4.04	7.91	9.74	19.09	28.22	37.05	45.49	53.64	61.60	69.27	76.58	83.65	90.51	97.00	102.88
39.00%	1.07	2.04	3.95	7.73	9.47	18.58	27.50	36.13	44.28	52.33	59.92	67.55	74.56	81.49	88.14	94.54	100.49
42.50%	1.05	2.02	3.89	7.56	9.28	18.18	26.89	35.33	43.38	51.14	58.83	66.05	73.15	80.00	86.52	92.49	98.15
46.00%	1.03	2.00	3.83	7.42	9.12	17.81	26.42	34.62	42.51	50.20	57.54	64.66	71.60	78.25	84.62	90.61	96.14
49.00%	1.01	1.98	3.78	7.31	8.96	17.55	25.92	34.08	41.96	49.30	56.58	63.56	70.38	76.87	83.37	89.09	94.65
52.00%	0.99	1.95	3.74	7.20	8.84	17.20	25.50	33.47	41.25	48.50	55.69	62.72	69.10	75.63	81.93	87.81	93.03
55.00%	0.98	1.91	3.68	7.11	8.70	16.99	25.09	33.09	40.62	47.86	54.81	61.64	68.31	74.41	80.56	86.38	91.76
58.00%	0.97	1.87	3.62	7.01	8.57	16.72	24.75	32.61	40.03	47.05	54.10	60.67	67.18	73.41	79.30	85.01	90.22
60.50%	0.96	1.84	3.57	6.93	8.49	16.52	24.44	32.26	39.60	46.56	53.42	59.95	66.36	72.44	78.35	83.97	89.12
63.00%	0.96	1.82	3.52	6.86	8.41	16.37	24.12	31.91	39.12	45.89	52.74	59.41	65.64	71.75	77.63	83.21	88.15
65.50%	0.95	1.81	3.48	6.80	8.33	16.21	23.95	31.64	38.73	45.55	52.35	58.79	65.01	71.01	76.85	82.39	87.38
67.50%	0.95	1.80	3.46	6.74	8.27	16.10	23.79	31.40	38.39	45.26	52.00	58.38	64.62	70.50	76.31	81.78	86.78
70.00%	0.94	1.80	3.43	6.68	8.20	15.98	23.64	31.12	38.10	44.90	51.55	57.95	64.11	70.07	75.74	81.15	86.09
78.50%	0.93	1.77	3.36	6.50	8.01	15.67	23.13	30.44	37.17	43.95	50.26	56.59	62.61	68.44	74.21	79.29	84.08
86.00%	0.93	1.75	3.32	6.37	7.82	15.29	22.61	29.70	36.44	42.89	49.18	55.52	61.23	67.21	72.56	77.81	82.26
92.50%	0.92	1.74	3.28	6.29	7.69	14.97	22.17	29.22	35.85	42.07	48.46	54.45	60.27	65.77	71.18	76.28	80.97
100%	0.91	1.73	3.24	6.19	7.58	14.75	21.79	28.76	35.28	41.48	47.64	53.52	59.21	64.61	69.95	74.98	79.59

Based on this measurement step, the luminance efficacy can be computed for each number of sustain pulses and load to provide the efficacy of each subfield compared with the luminance for the lowest non-zero load

(8,5% in the present case). The efficacy results are given in the table below the values of load and sustain pulses number of the previous table. In this table, the efficacy of 100% is allocated to the values obtained for a load of 8.5%.

		Sustain pulses number																	
		1	2	4	8	10	20	30	40	50	60	70	80	90	100	110	120	130	Mean
Load (%)	8.50%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100%
	12.00%	99.24	98.58	98.24	98.15	98.11	97.88	97.98	98.00	97.96	98.24	97.89	98.07	97.94	97.90	98.20	97.92	98.34	98.01%
	14.50%	98.67	97.45	96.93	96.65	96.54	96.43	96.34	96.41	96.40	96.40	96.50	96.26	96.29	96.59	96.44	95.66	96.40	96.36%
	17.00%	98.10	96.46	95.79	95.30	95.35	94.95	95.04	95.16	95.07	94.80	94.96	95.01	94.98	94.93	94.94	94.96	94.81	95.01%
	19.50%	97.33	95.61	94.56	94.05	93.86	93.50	93.52	93.71	93.62	93.52	93.47	93.45	93.46	93.45	93.70	93.53	93.54	93.57%
	21.00%	96.95	95.04	93.94	93.20	93.00	92.69	92.82	92.83	92.85	92.57	92.73	92.69	92.62	92.66	92.69	92.76	92.55	92.74%
	23.00%	96.19	94.19	92.98	92.35	92.05	91.58	91.63	91.97	91.77	91.60	91.62	91.57	91.63	91.55	91.78	91.64	91.62	91.70%
	24.50%	95.24	93.77	92.36	91.50	91.27	90.89	90.80	91.05	91.07	90.71	90.92	90.88	90.78	90.85	90.86	90.80	90.71	90.91%
	26.00%	94.10	93.06	91.75	90.70	90.53	89.97	90.08	90.24	90.21	90.02	89.99	89.92	89.73	89.93	90.02	90.08	89.30	90.06%
	27.00%	93.33	92.63	91.22	90.25	89.99	89.44	89.48	89.79	89.73	89.41	89.48	89.37	89.53	89.49	89.56	89.50	89.38	89.56%
	29.00%	92.19	91.08	90.08	89.30	89.13	88.61	88.46	88.79	88.66	88.40	88.58	88.51	88.54	88.46	88.53	88.64	88.34	88.61%
	30.00%	91.62	90.23	89.46	88.70	88.51	87.91	87.97	88.31	88.03	87.89	87.93	87.83	87.89	87.88	88.03	87.95	87.87	88.01%
	31.00%	91.24	89.38	88.67	88.20	87.97	87.36	87.40	87.72	87.51	87.33	87.36	87.36	87.35	87.38	87.45	87.42	87.29	87.47%
	32.50%	90.86	88.53	87.80	87.30	87.19	86.67	86.76	86.98	86.55	86.68	86.66	86.58	86.75	86.60	86.69	86.76	86.72	86.74%
	33.50%	90.48	88.10	86.92	86.20	86.53	86.09	86.12	86.32	85.95	86.03	85.98	86.02	85.69	86.13	86.20	86.14	86.01	86.10%
	34.50%	90.29	87.68	86.57	86.10	86.04	85.65	85.74	85.76	85.58	85.48	85.55	85.60	85.56	85.59	85.69	85.71	85.47	85.66%
	39.00%	89.14	86.26	84.64	84.10	83.69	83.36	83.56	83.62	83.32	83.40	83.22	83.47	83.30	83.38	83.45	83.54	83.49	83.44%
	42.50%	87.81	85.41	83.41	82.25	82.00	81.59	81.70	81.77	81.62	81.49	81.70	81.62	81.73	81.85	81.92	81.73	81.54	81.73%
	46.00%	85.71	84.42	82.09	80.70	80.60	79.91	80.26	80.14	79.99	80.00	79.91	79.90	80.00	80.06	80.11	80.06	79.87	80.08%
	49.00%	83.81	83.57	81.04	79.50	79.16	78.76	78.74	78.88	78.95	78.56	78.58	78.55	78.64	78.65	78.93	78.72	78.64	78.76%
	52.00%	82.48	82.29	80.16	78.35	78.13	77.19	77.45	77.48	77.61	77.28	77.33	77.51	77.21	77.38	77.57	77.60	77.29	77.48%
	55.00%	81.52	80.59	79.02	77.35	76.89	76.24	76.21	76.59	76.43	76.27	76.11	76.17	76.33	76.13	76.27	76.33	76.23	76.33%
	58.00%	80.57	79.18	77.70	76.25	75.78	75.03	75.20	75.48	75.32	74.97	75.14	74.97	75.06	75.11	75.08	75.12	74.95	75.19%
	60.50%	80.00	77.90	76.56	75.45	75.00	74.14	74.25	74.67	74.50	74.21	74.19	74.08	74.15	74.12	74.18	74.20	74.04	74.31%
	63.00%	79.62	77.05	75.42	74.70	74.34	73.47	73.28	73.85	73.61	73.13	73.24	73.41	73.34	73.42	73.50	73.53	73.23	73.51%
	65.50%	79.24	76.63	74.63	74.00	73.60	72.72	72.76	73.22	72.87	72.59	72.70	72.65	72.64	72.66	72.76	72.80	72.60	72.83%
	67.50%	78.86	76.20	74.10	73.35	73.11	72.22	72.28	72.67	72.24	72.12	72.21	72.14	72.20	72.14	72.25	72.26	72.09	72.32%
	70.00%	78.67	75.92	73.49	72.65	72.49	71.69	71.82	72.04	71.68	71.55	71.58	71.61	71.63	71.70	71.71	71.71	71.53	71.77%
	78.50%	77.90	74.79	72.08	70.75	70.76	70.30	70.27	70.45	69.94	70.03	69.79	69.93	69.96	70.02	70.26	70.06	69.85	70.15%
	86.00%	77.14	74.08	71.20	69.35	69.15	68.60	68.68	68.75	68.57	68.35	68.30	68.60	68.41	68.77	68.70	68.76	68.34	68.64%
	92.50%	76.57	73.51	70.32	68.40	68.00	67.17	67.36	67.64	67.46	67.04	67.30	67.28	67.34	67.29	67.39	67.40	67.27	67.39%
	100%	76.00	72.95	69.53	67.40	66.97	66.18	66.20	66.57	66.38	66.11	66.16	66.13	66.15	66.11	66.22	66.25	66.12	66.29%

A luminance attenuation representative of the load effect can be deduced from these efficacy values for each subfield :

Attenuation = 100% - efficacy

The previous table shows that, in fact, the load effect is quite independent from the number of sustain pulses. Indeed, if we except the values obtained for the very low sustain pulses number where a lot of measuring failures could be done (because luminance is too low), it can be seen that globally the attenuation for a given picture load is quite stable. The efficacy can be approximated to the mean value (without taking into account the first values) for each. The left column of the table gives this mean value for each load. Figure 7 shows a curve illustrating the mean value of efficacy versus load. As it can be seen on this curve, the evolution of the efficacy versus the load is quite monotonous and smooth. It is a reason why it is possible to calculate an attenuation value (representative of load effect) for some load values by interpolation of measuring points. This curve is used to compute a correction value for each subfield.

The minimal efficacy (66.29%) is obtained for a load of 100%. It corresponds to a luminance attenuation of 33.71%.

In order to have an homogeneous luminance behavior of the subfield independently of the load, the invention proposes to adjust the number of sustain pulses per subfield to get an efficacy of 66.29% for each subfield. For example, for a subfield that should have 107 sustain pulses after rescaling by APL:

- If the load is 100%, there is nothing to do and the 107 sustain pulses of current subfield are kept. In that case, 107 sustain pulses are as luminous as a subfield with 107x0.6629=71 sustain pulses with no luminance attenuation;
- If the load is only 70%, the efficacy is 71,77%. For achieving the same luminance than for a 100% load, it is necessary to apply a correction of x sustain pulses verifying the following equation: $(107-x)\times 0.7177=71$. In that case, x=8. The correction consists in

subtracting 8 sustain pulses to the theoretical number of sustain pulses of the subfield.

- If the load is 30%, the efficacy is 88.01%. For achieving the same luminance than for a 100% load, it is necessary to apply a correction of x sustain pulses verifying the following equation: $(107-x)\times 0.8801=71$. In that case, x=26. The correction consists in subtracting 26 sustain pulses to the theoretical number of sustain pulses of the subfield.
- If the load is 17%, the efficacy is 95.01%. For achieving the same luminance than for a 100% load, it is necessary to apply a correction of x sustain pulses verifying the following equation: $(107-x)\times 0.9501=71$. In that case, x=32. The correction consists in subtracting 32 sustain pulses to the theoretical number of sustain pulses of the subfield.

This adjustment step for a subfield SFn can be illustrated by the following equation :

$$NB_2[SFn]= NB_1(SFn)-Corr[SFn,Load(SFn)]$$

where

- $NB_1(SFn)$ is the number of sustain pulses of the subfield SFn before adjustment,
- $NB_2(SFn)$ is the number of sustain pulses of the subfield SFn after adjustment, and
- Corr[SFn,Load(SFn)] is the correction value calculated for the subfield SFn whose charge is Load(SFn).

In a variant, as the luminance attenuation does not vary much with the number of sustain pulses, it is possible, for achieving the correction values, to measure the luminance produced by a plurality of luminous elements of the display panel for only a specific number of sustain pulses and for all the precited loads. A value of the luminance attenuation compared with a reference luminance measured for the highest one of said loads is then

determined for each one of said loads. A correction value can be then computed, for each one of said loads and for said specific first number of sustain pulses, by multiplying the determined luminance attenuation with said specific first number of sustain pulses.

Redistribution of the subtracted sustain pulses

In the preceding step, the subfields are corrected to deliver a maximum of 66.29% of luminance. Consequently, the maximal peak luminance of the display is reduced.

According the invention, it is proposed to rescale the number of sustain pulses of each subfield by redistributing in each subfield an amount of the sustain pulses that have been removed during the preceding step proportionally to its new number of sustain pulses.

To this end, the correction values of all subfields are summed up by a counter. This sum is called CorrSum :

$$\text{CorrSum} = \sum_{n=0}^{n=10} \text{Corr}[\text{SFn};\text{Load}(\text{SFn})]$$

The redistribution of the subtracted sustain pulses can be illustrated by the following equation :

$$NB_3(SFn) = NB_2(SFn) + NB_2(SFn) \times \frac{\text{CorrSum}}{\sum_{n=0}^{n=10} NB_2(SFn)}$$

where $NB_3(SFn)$ is the number of sustain pulses of the subfield SFn after redistribution of the subtracted sustain pulses.

Circuit implementation

Figure 8 illustrates a possible circuit implementation of the inventive method. The input picture data RGB are forwarded to a degamma block 10 where the following operation is applied

$$D_{OUT} = 65535 \times \left(\frac{D_{IN}}{1023}\right)^{\gamma}$$

where D_{IN} are the input data,

D_{OUT} are the output data, and

γ=2.2.

The input data comprise 10 bits in our example whereas the output data have 16 bits. The output data are summed up by an Average Power Measure Block 12 to deliver an Average Power Level (APL) as described previously. A first number of sustain pulses $NB_1(SFn)$ is determining for each subfield SFn by a Power management LUT 13 receiving the APL value in order that the average power needed by the PDP for displaying the picture be approximately equal to a predetermined target value.

The output data from the degamma block 10 are in parallel processed by a dithering block 11 to come back to a 8 bits resolution The data outputted by the dithering block 11 are coded in subfield data by an encoding block 14. The subfield data are then stored in a frame memory 15. The amount of active pixel Load(SFn) for each subfield SFn is computed by a load subfield block 16.

Based on Load(SFn) and $NB_1(SFn)$, a correction LUT 17 defines the correction value Corr(SFn,Load(SFn)) to be subtracted to the number of sustain pulses $NB_1(SFn)$. Another block 18 is used to achieve the following operation $NB_1(SFn)$-Corr(SFn,Load(SFn)). The new number of sustain pulses of the subfield SFn is referenced $NB_2(SFn)$.

A block 19 is then used for redistributing the subtracted sustain pulses in all the subfields proportionally to their number of sustain pulses $NB_2(SFn)$ and achieves the following operation :

$$NB_3(SFn) = \left(NB_2(SFn)\cdot\left[1+\frac{CorrSum}{\sum NB_2(SFn)}\right]\right)$$

The numbers of sustain pulses are computed and used to control the PDP to display the subfield data stored in the frame memory 15 and converted in series.

The load effect compensation concept of the present invention is based on a LUT 17 having two inputs: the number of sustain pulses and the

subfield load. It delivers the amount of sustain pulses that should be subtracted to the number of sustain pulses to obtain the same luminance than a full loaded subfield. Such a LUT is illustrated by figure 9

In the previously described example, the number of sustain pulses is going from 1 to 339. The table comprises 339 horizontal inputs. For achieving a precision of 6 bits for the load effect, the subfield load should be expressed with 6 bits. The table comprises 64 vertical inputs. The maximal correction that should be applied is linked to the value 339 that should be adjusted to an attenuation of 33,71% (in this case, 114 sustain pulses should be subtracted). This means that a precision of 7 bits is needed for the correction. In that case, the overall memory requirements will be around 339x64x7bits=148kbits.

For each number of sustain pulses contained by the current subfield (1 to 339) and for each load of this subfield (measured with a step of 1.5%), the LUT 17 provides the exact amount of sustain pulses that should be subtracted from the original amount of sustain pulses.

The utilization of this table requires to compute, for each subfield, its global load (the number of activated luminous elements divided by the total amount of luminous elements). To this end, the load subfield block 16 comprises 11 counters (preferably, 16 counters are planned to cover up to 16 subfield modes), one for each bit of the subfield data and each of them being reset at each frame on the V sync pulse. Then, for each pixel, the appropriate subfield counter is incremented by the corresponding bit of the subfield data. Each counter is incremented by the value of the bit of the subfield data (0 if the subfield is not activated for the current video value and 1 if activated). If the three colors are handled serially (one color at a time with the same encoder), 11 counters are sufficient. Otherwise, if the three colors are encoded in parallel with three LUTs, we will have 33 counters. The size of the counters depends on the maximal amount of analyzed luminous elements: a WXGA panel comprises 1365x768x3=3144960 luminous elements which means a 22 bits counter (2^{22}=4194304). The outputs of the

counters are limited to 7 bits since a precision of 7 bits for the subfield load computation is sufficient.

In order to improve the working of the circuit, it is possible to add a hysteresis function on the output value of the load subfield block 16 in order to avoid any jitter or oscillation. This corresponds to a kind of filtering of the value of the subfield load.

As this solution is based on a LUT and is fully independent to the subfield structure used, the hardware implementation is very reduced.

CLAIMS

1. Method for processing data of a picture to be displayed on display means with persistent luminous elements during a frame comprising a plurality of subfields of at least two different weights, a number of sustain pulses being associated to each subfield, characterized in that it comprises the following steps :
- encoding the picture data into subfield data,
- calculating the load of each subfield on the basis of said subfield data, and
- adjusting the number of sustain pulses of the subfields on the basis of their loads in order to have a same relation of proportionality between the luminance produced by the persistent luminous elements for the subfields and their weights.

2. Method according to Claim 1, characterized in that, for adjusting the number of sustain pulses of a subfield, it comprises the following steps :
- providing a first number of sustain pulses (NB_1) for said subfield,
- defining a correction value to be subtracted to said first number of sustain pulses on the basis of the load and the first number of sustain pulses of said subfield,;
- subtracting said correction value from said first number of sustain pulses in order to have a second number of sustain pulses (NB_2) for said subfield.

3. Method according to Claim 2, characterized in that the correction values of the subfields are defined by a look up table with the load and the number of sustain pulses of said subfield as input signals.

4. Method according to Claim 3, characterized in that the correction values stored in the look up table are achieved by the following steps :
- measuring the luminance produced by a plurality of luminous elements of the display means for all first numbers of sustain pulses comprised between

1 and the first number of sustain pulses M of the highest weight subfield and for a plurality of non-zero loads,
- determining, for each one of said first numbers of sustain pulses and each one of said loads, the luminance attenuation compared with a reference luminance measured for the same number of sustain pulses and the highest one of said loads, and
- computing, for each one of said first numbers of sustain pulses and each one of said loads, the correction value by multiplying the determined luminance attenuation with said first number of sustain pulses.

5. Method according to Claim 3, characterized in that the correction values included in the look up table are achieved by the following steps :
- measuring the luminance produced by a plurality of luminous elements of the display means for a specific first number of sustain pulses and for a plurality of non-zero loads,
- determining, for each one of said loads, the luminance attenuation compared with a reference luminance measured for the highest one of said loads, and
- computing, for each one of said loads and for said specific first number of sustain pulses, the correction value by multiplying the determined luminance attenuation with said specific first number of sustain pulses.

6. Method according to Claim 5, characterized in that the specific first number of sustain pulses is greater than 20.

7. Method according to one of Claims 2 to 6, characterized in that the second numbers of sustain pulses of the plurality of subfields are rescaled in order to redistribute in each subfield an amount of the subtracted sustain pulses proportionally to its second number of sustain pulses.

8. Method according to one of claims 1 to 7, characterized in that, before the step of adjusting the number of sustain pulses of each subfield on

the basis of its load, said number of sustain pulses is rescaled in order that the average power level needed by the display means for displaying the picture be approximately equal to a fixed target value.

9. Method according to one of claims 1 to 8, characterized in that the calculation of the load of a subfield consists in counting the luminous elements to be illuminated during said subfield.

10. Device for processing data of a picture to be displayed on display means with persistent luminous elements during a frame comprising a plurality of subfields of at least two different weights, a number of sustain pulses being associated to each subfield, characterized in that it comprises :

- means (14) for encoding the picture data into subfield data,
- means (16) for calculating the load of each subfield on the basis of said subfield data, and
- means (17,18) for adjusting the number of sustain pulses of the subfields on the basis of their load in order to have a same relation of proportionality between the luminance produced by the persistent luminous elements for the subfields and their weights.

11. Device according to Claim 10, characterized in that the means for adjusting the number of sustain pulses of a subfield comprises :

- means (12,13) for providing a first number of sustain pulses (NB_1) for said subfield,
- correction means (17) for defining a correction value to be subtracted to said first number of sustain pulses on the basis of the load and the number of sustain pulses of said subfield; and
- means (18) for subtracting said correction value from said first number of sustain pulses in order to have a second number of sustain pulses (NB_2) for said subfield.

12. Device according to Claim 11, characterized in that the correction means are a look up table (17) with the load and the number of sustain pulses of said subfield as input signals.

13. Device according to Claim 12, characterized in that the correction values stored in the look up table (17) are achieved by :

- measuring the luminance produced by a plurality of luminous elements of the display means for all first numbers of sustain pulses comprised between 1 and the first number of sustain pulses M of the highest weight subfield and for a plurality of non-zero loads,
- determining, for each one of said first numbers of sustain pulses and each one of said loads, the luminance attenuation compared with a reference luminance measured for the same number of sustain pulses and the highest one of said loads, and
- computing, for each one of said first numbers of sustain pulses and each one of said loads, the correction value by multiplying the determined luminance attenuation with said first number of sustain pulses.

14. Device according to Claim 12, characterized in that the correction values stored in the look up table (17) are achieved by :

- measuring the luminance produced by a plurality of luminous elements of the display means for a specific first number of sustain pulses and for a plurality of non-zero loads,
- determining, for each one of said loads, the luminance attenuation compared with a reference luminance measured for the highest one of said loads, and
- computing, for each one of said loads and for said specific first number of sustain pulses, the correction value by multiplying the determined luminance attenuation with said specific first number of sustain pulses.

15. Device according to Claim 14, characterized in that the specific first number of sustain pulses is greater than 20.

16. Device according to one of Claims 11 to 15, characterized in that it comprises means (19) for rescaling the second numbers of sustain pulses of the plurality of subfields in order to redistribute in each subfield an amount of the subtracted sustain pulses proportionally to its second number of sustain pulses.

17. Device according to one of claims 10 to 16, characterized in that it comprises means (12,13) for rescaling, before adjusting the number of sustain pulses of each subfield on .the basis of its load, said number of sustain pulses in order that the average power level needed by the display means for displaying the picture be approximately equal to a fixed target value.

18. Plasma display panel comprising a plurality of persistent luminous elements organized in rows and columns, characterized in that it comprises a device according to one of the claims 10 to 17 for compensating load effect.

ABSTRACT

METHOD AND DEVICE FOR COMPENSATING LOAD EFFECT

The present invention relates to a method for compensating load effect in a display panel with persistent luminous elements. The method comprises the following steps :

- encoding the picture data into subfield data,
- calculating the load of each subfield on the basis of said subfield data, and
- adjusting the number of sustain pulses of each subfield on the basis of its load in order to have a relation of proportionality between the luminance produced by the persistent luminous elements for the subfield and its weight.

FIG 8

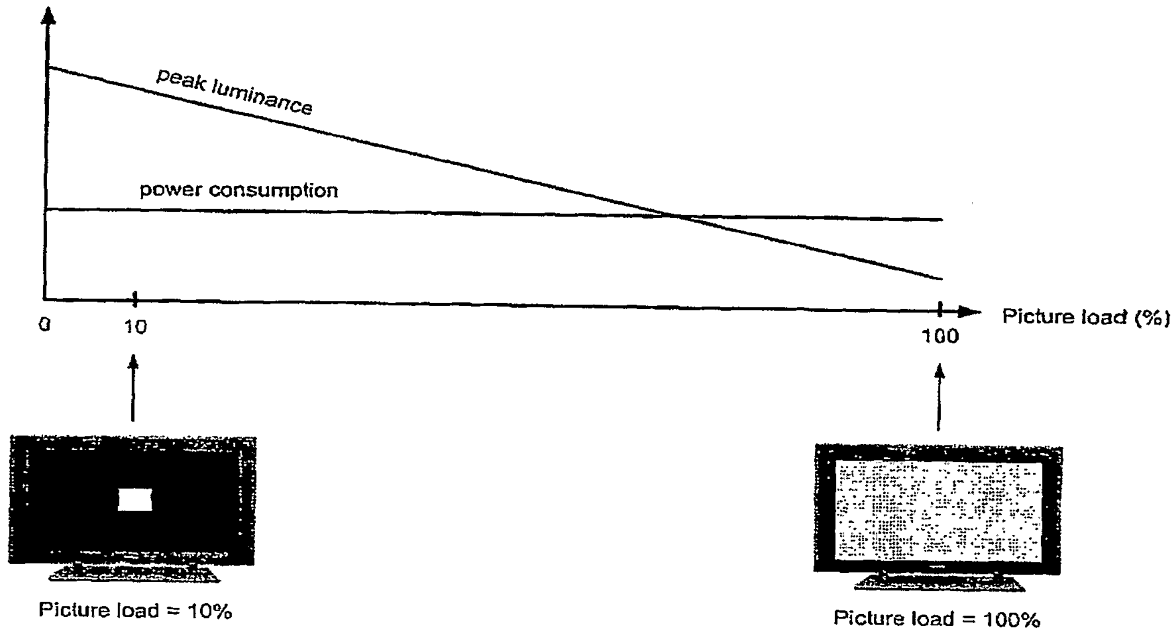

peak luminance
power consumption
0
10
100
Picture load (%)
Picture load = 10%
Picture load = 100%

FIG.1

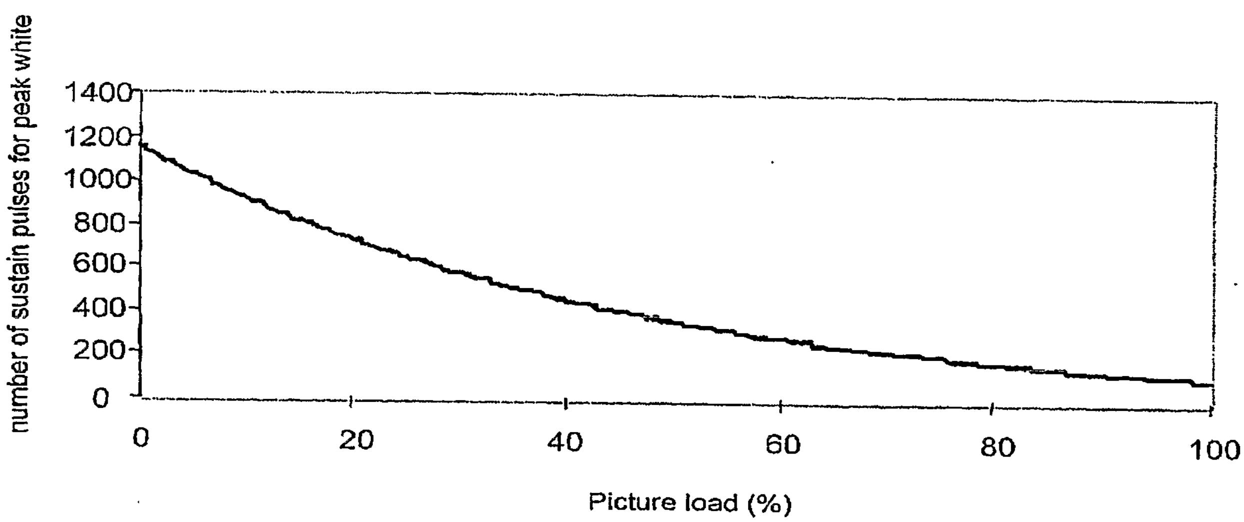

number of sustain pulses for peak white
1400
1200
1000
800
600
400
200
0
0
20
40
60
80
100
Picture load (%)

FIG.2

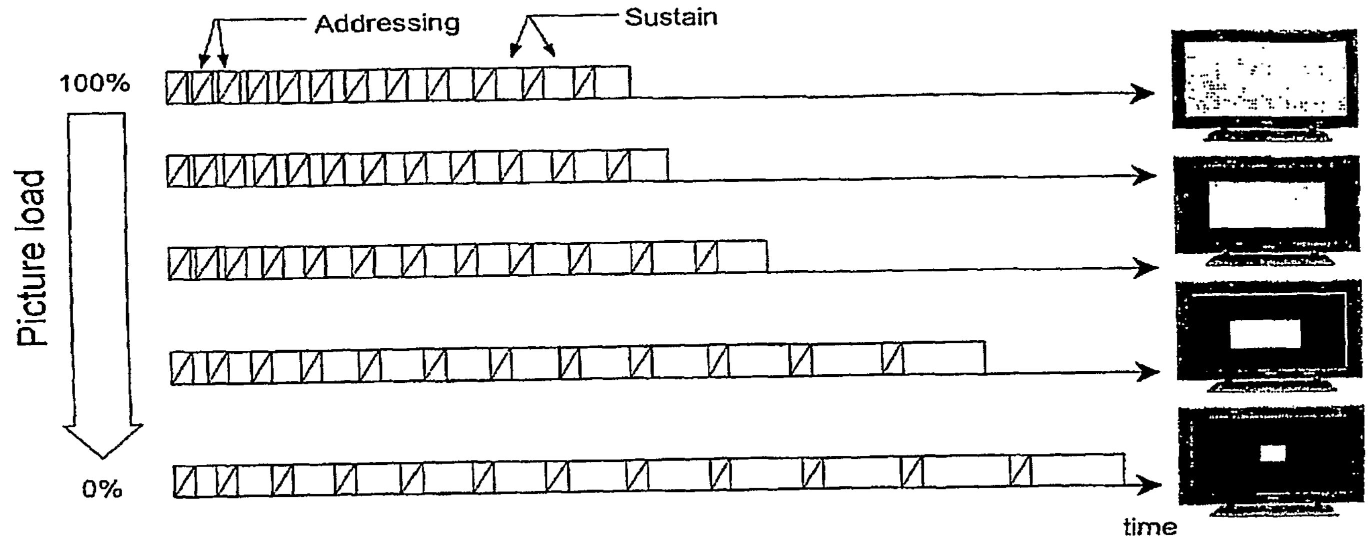

Addressing
Sustain
100%
Picture load
0%
time

FIG.3

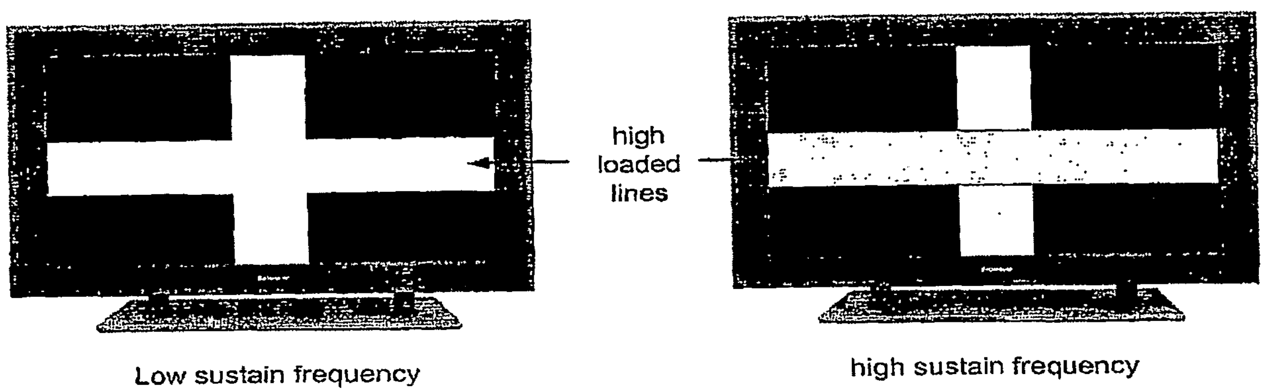

high
loaded
lines
Low sustain frequency
high sustain frequency

FIG.4

Low sustain frequency

High sustain frequency

FIG.5

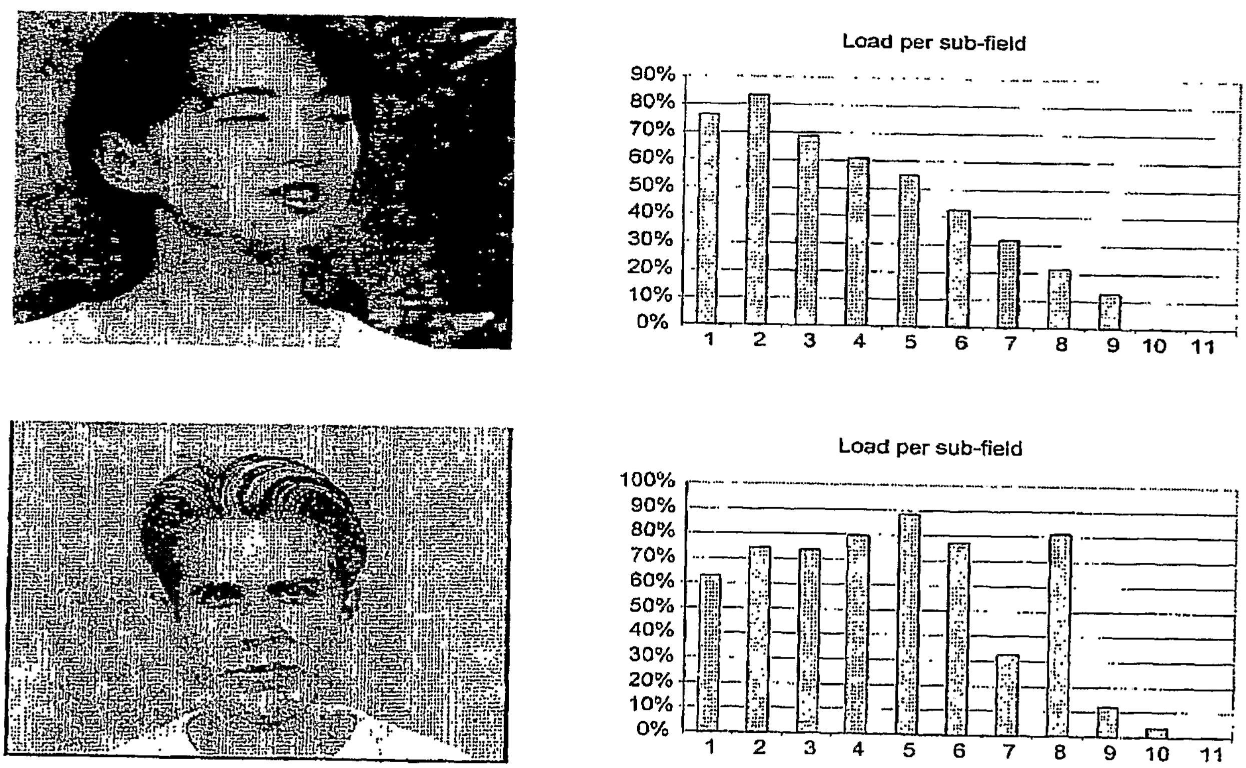


FIG.6

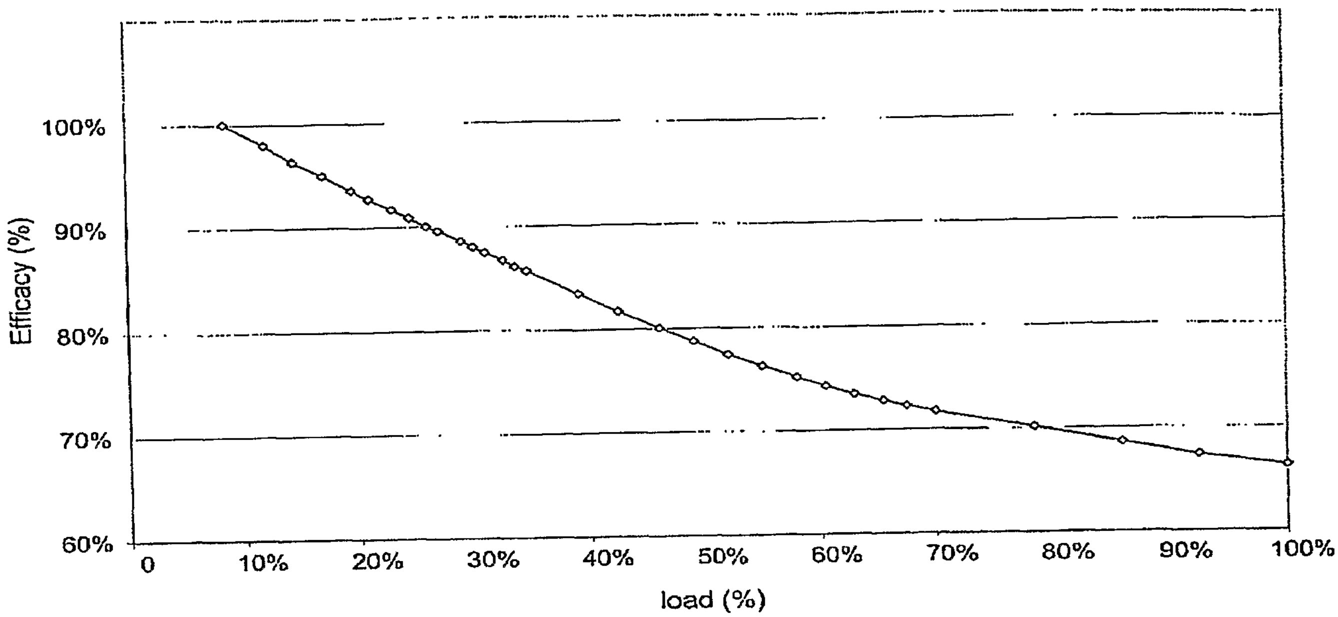
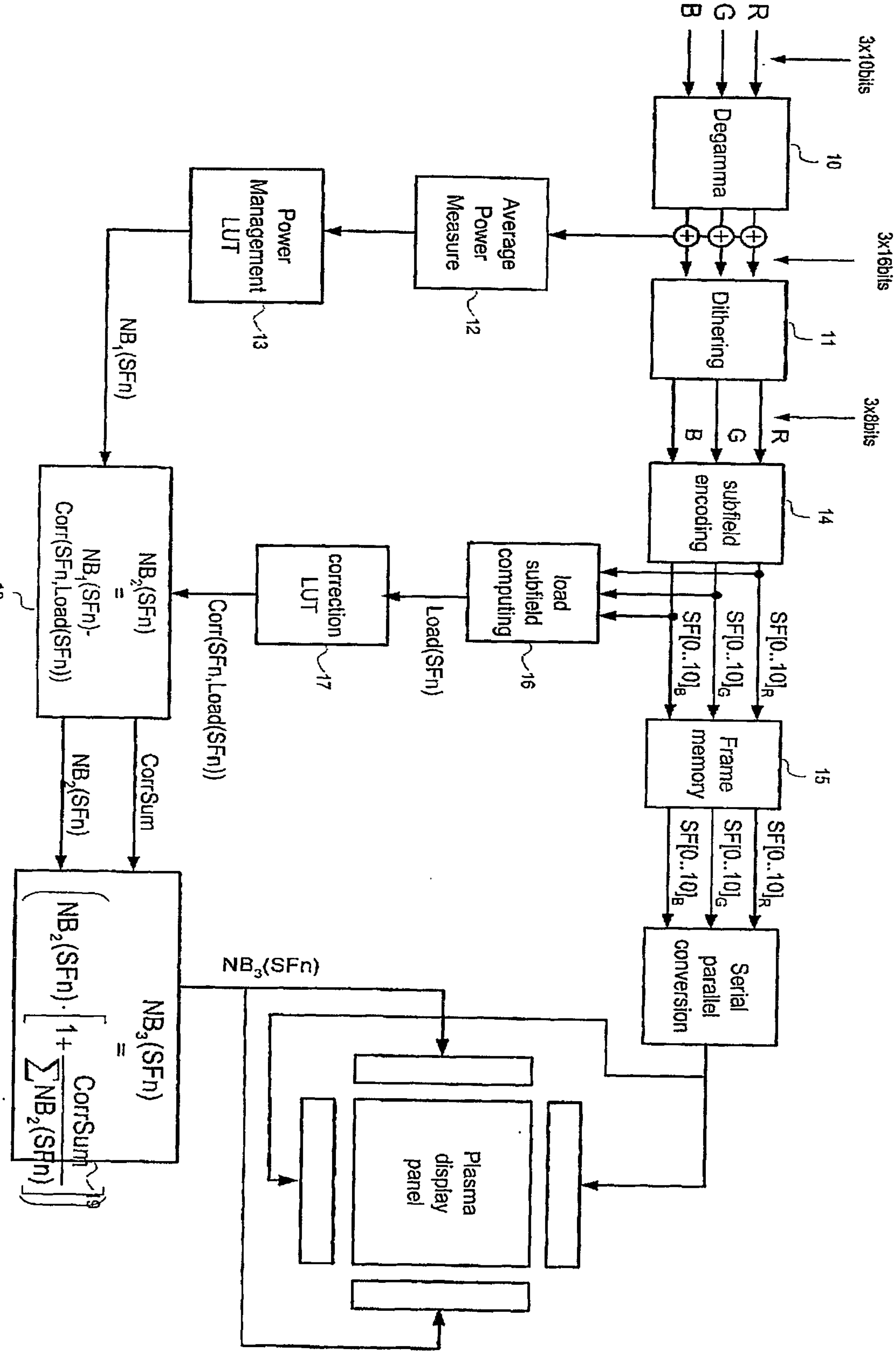


FIG.7



3x10bits
R
G
B
Degamma
10
3x16bits
Dithering
11
3x8bits
R
G
B
subfield encoding
14
SF[0..10]$_R$
SF[0..10]$_G$
SF[0..10]$_B$
Frame memory
15
SF[0..10]$_R$
SF[0..10]$_G$
SF[0..10]$_B$
Serial parallel conversion
Average Power Measure
12
Power Management LUT
13
NB$_1$(SFn)
load subfield computing
16
Load(SFn)
correction LUT
17
Corr(SFn,Load(SFn))
NB$_2$(SFn) = NB$_1$(SFn)- Corr(SFn,Load(SFn))
18
CorrSum
NB$_2$(SFn)
NB$_3$(SFn) = $\left(NB_2(SFn)\cdot\left[1+\frac{CorrSum}{\sum NB_2(SFn)}\right]\right)$
19
NB$_3$(SFn)
Plasma display panel

FIG.8

17

Sustain pulses number	Load (%) 0	1.5	3	17	30	70	100
1	0	0	0	0	0	0	0
2	1	1	1	1	0	0	0
3	1	1	1	1	1	0	0
107	36	36	36	32	26	8	0
339	114	114	114	102	84	26	0

Correction values

FIG.9